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Great Lakes Bioenergy Research Center

U.S. DEPARTMENT OF ENERGY

Tim Donohue
University of Wisconsin-Madison
GLBRC Director
Professor of Bacteriology

Fuel Synthesis & Sustainability Activities

Biomass 2009
March 17, 2009

COLLEGE OF AGRICULTURAL & LIFE SCIENCES
University of Wisconsin-Madison

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GLBRC Partners

Academic
UW-Madison
Michigan State University
Illinois State University
Iowa State University

DOE National Labs
Pacific Northwest NL
Oak Ridge NL

Industry
Lucigen/C5-6 Technologies

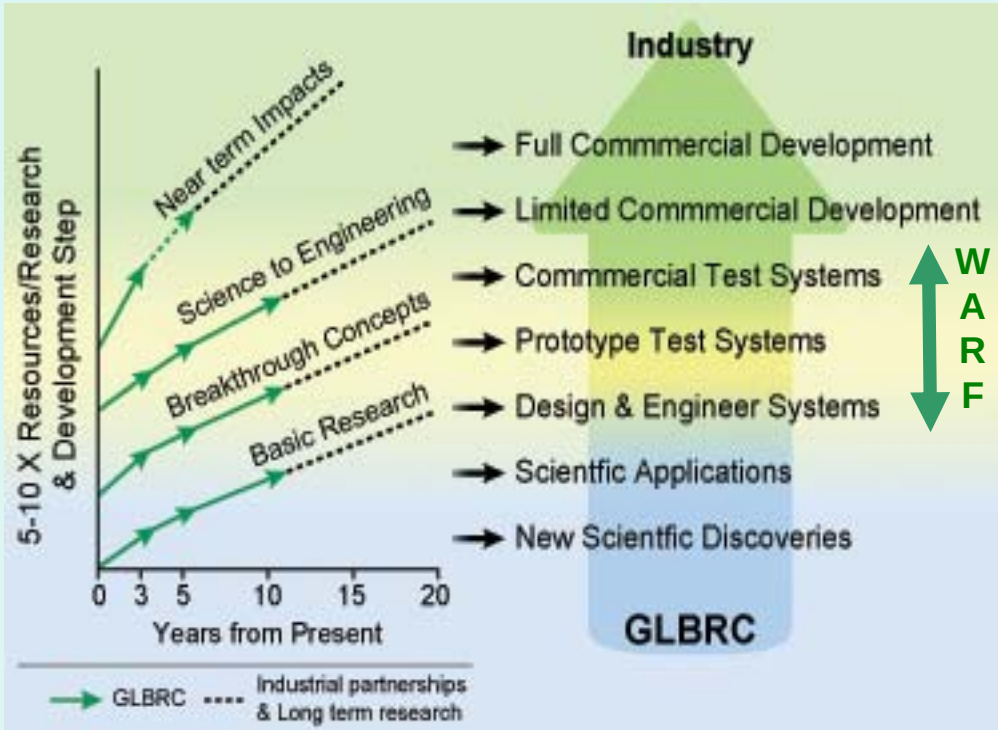
DOE Office of Science
Joint Genome Institute
BACTER Program
Advanced Scientific Computing

States of Wisconsin & Michigan
Facilities (WI) & faculty (WI/MI)

Technology Transfer
WARF, others

Advancing the Cellulosic Biofuels Mission

- genome-enabled analysis of model systems & bioenergy organisms/ecosystems
- scientific underpinnings of tomorrow's biofuels



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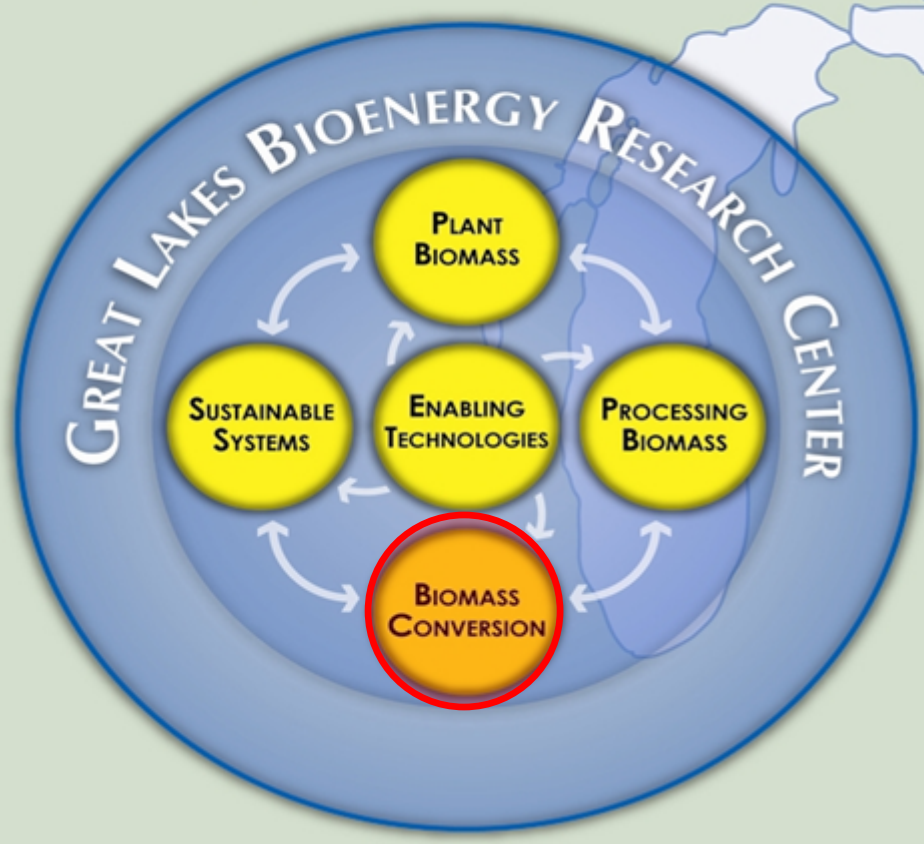
How will GLBRC advance the BRC mission?



Basic science to improve

- Bioenergy plants
- Biomass processing
- Conversion to fuels
- Biofuels sustainability

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Biomass conversion into energy products: improve methods for converting plant biomass into materials that can replace fossil fuels.

- *Microbial catalysts optimized for fuel synthesis*
  - production of lignocellulolytic enzymes
  - efficient use of 5- & 6-carbon sugar monomers & oligomers
  - ethanol and alternative fuel synthesis (biodiesel & alkanes)
  - stress, fuel & lignotoxin tolerance

Photosynthetic microbes optimized for

- H_2 production
- CO_2 sequestration into fuels

Chemical catalysts optimized for

- dehydration of sugars to furfurals and derivatives
- hydrogenation of furfurals and derivatives to high-energy fuels

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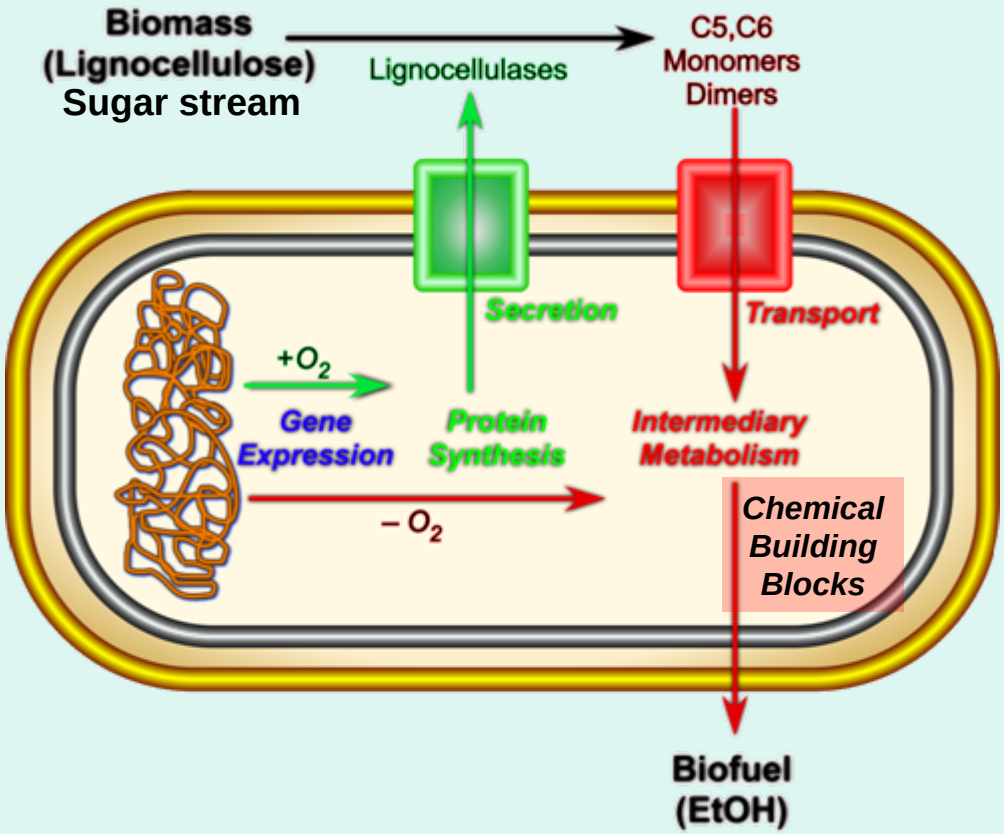
Improved Microbial Fuel Production



Phase 1: Aerobic growth, secrete degradative enzymes

Phase 2: Anaerobic growth (*fermentation*), activate enzymes & transporters to produce fuels/building blocks

Optimize sugar stream refining

- transport sugar mixtures
- produce fuels & building blocks
- resist cellulosic & fuel toxins

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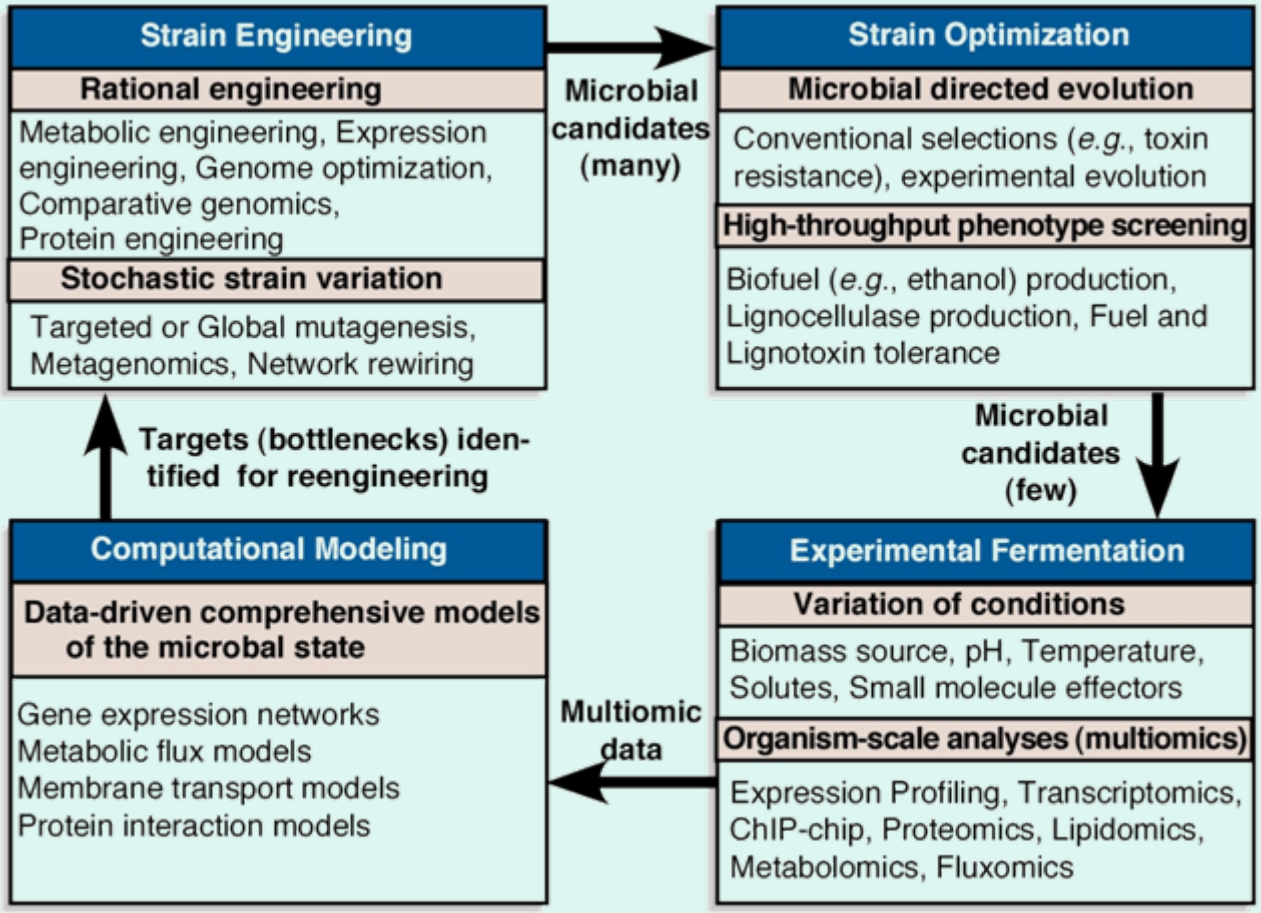
REDIME: **RE**iterative **D**irected **MI**crobial **E**volution

combines synthetic biology, computational & natural strain optimization



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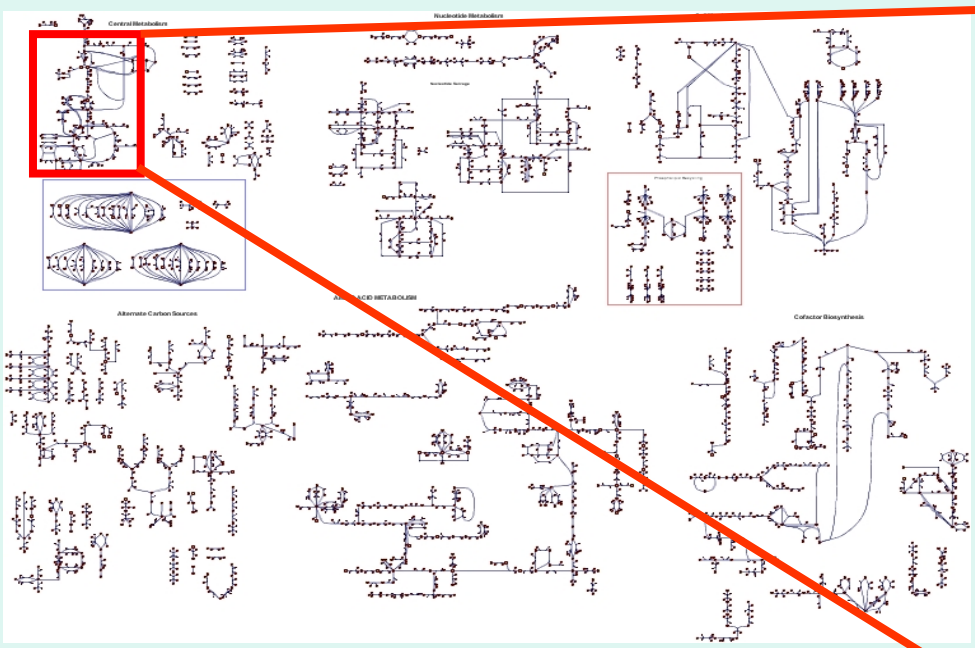
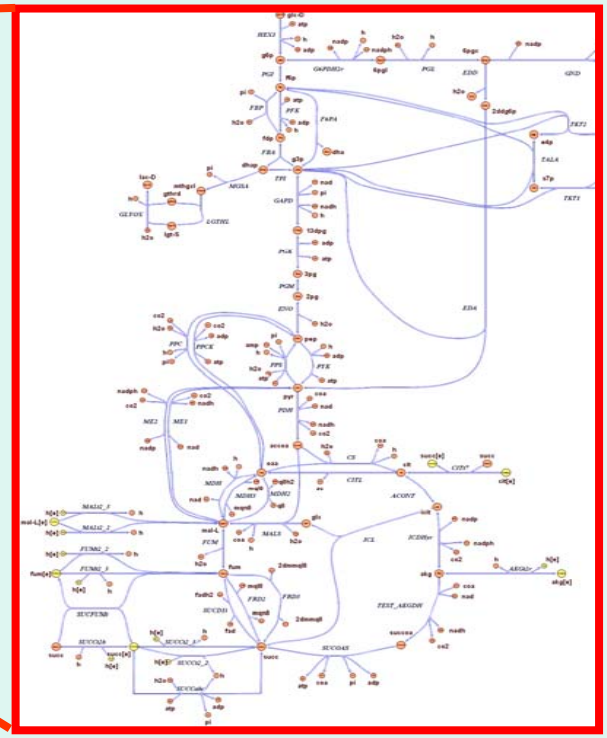
Optknock Modeling of Ethanologenesis

- Includes 904 *E. coli* metabolic genes (~20%), 931 reactions & 625 metabolites (updated from Reed et al. Genome Biology. 2003)
- Based on Ingram et al. strains, predict growth rates & fuel yields in combinations of single, double (6 x 10^4) & triple (7 x 10^7) knockouts





500 “winners” being evaluated in the lab

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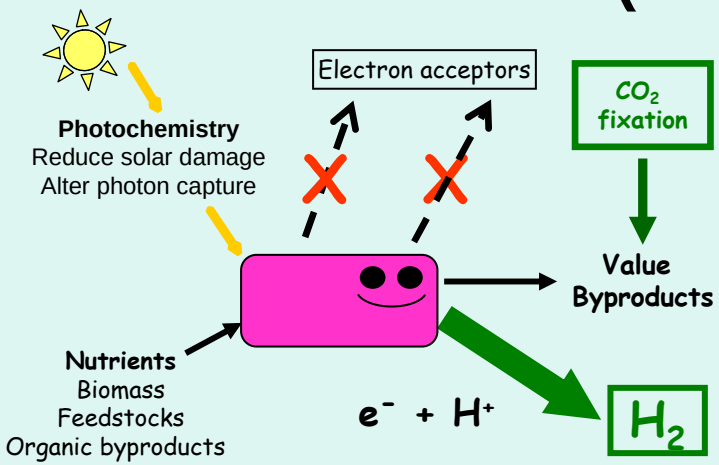
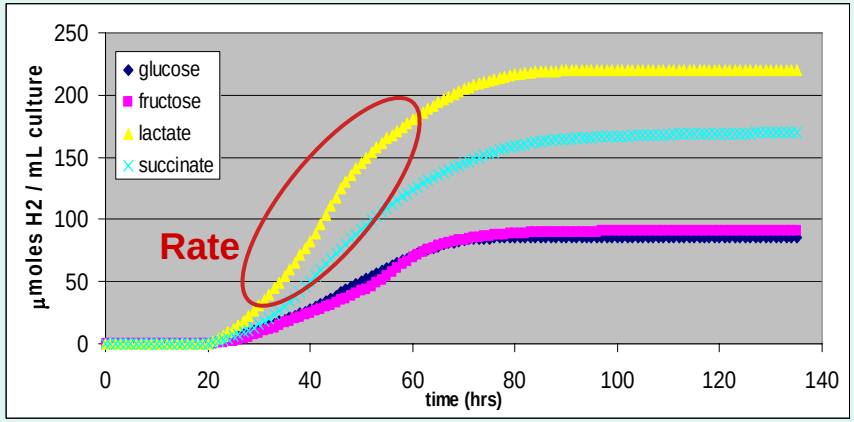
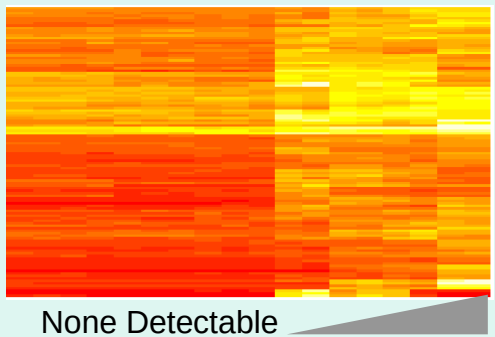
Solar- & biomass-powered fuel production (*Rhodobacter*)



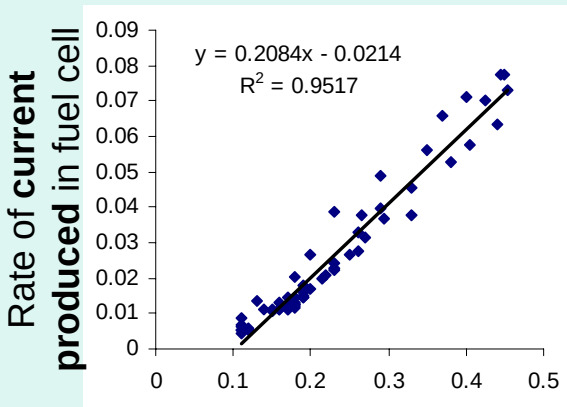




None Detectable

H_2 Accumulation

Hierarchical clustering of gene expression as H_2 accumulates



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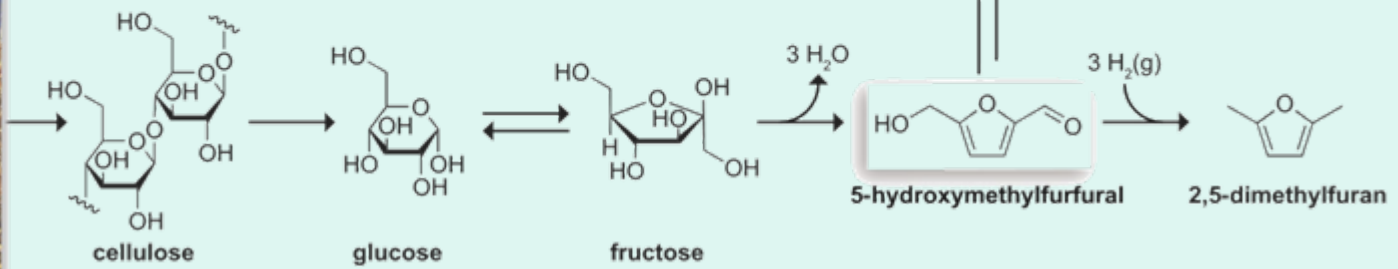
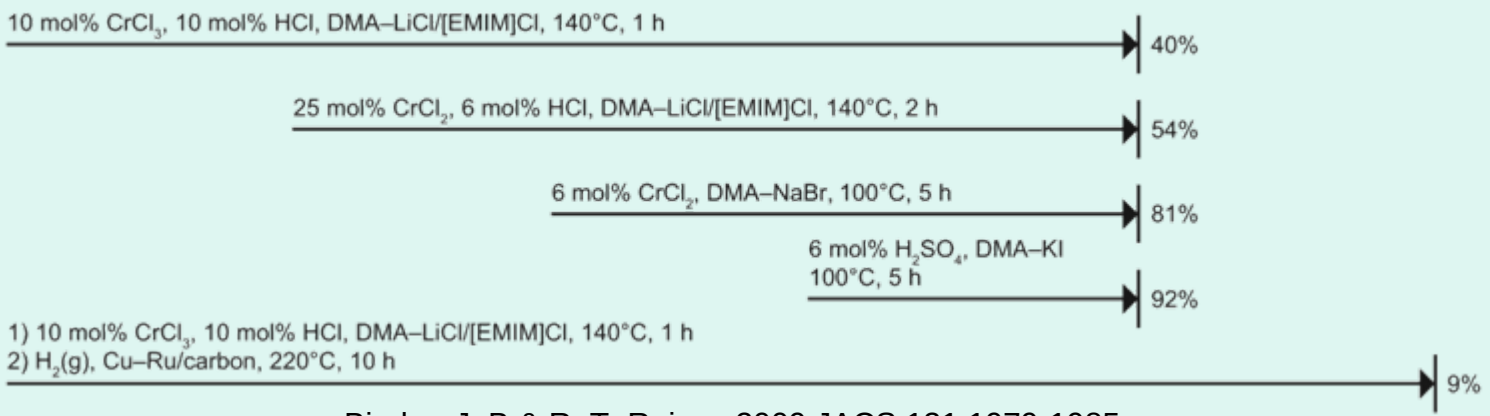
Conversion of lignocellulose to liquid fuel precursors, HMF & DMF

Weak ion pairing of Cl^- in dimethylacetamide allows cellulose dissolution and Cl^--mediated dehydration.

untreated corn stover





Binder, J. B & R. T. Raines 2009 JACS 131:1979-1985

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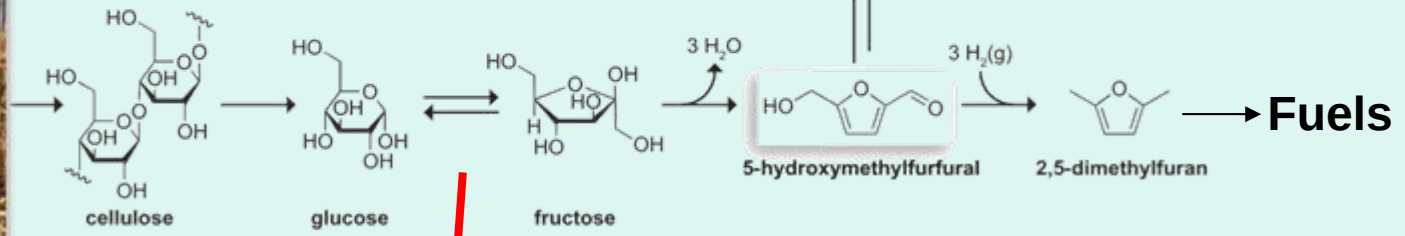
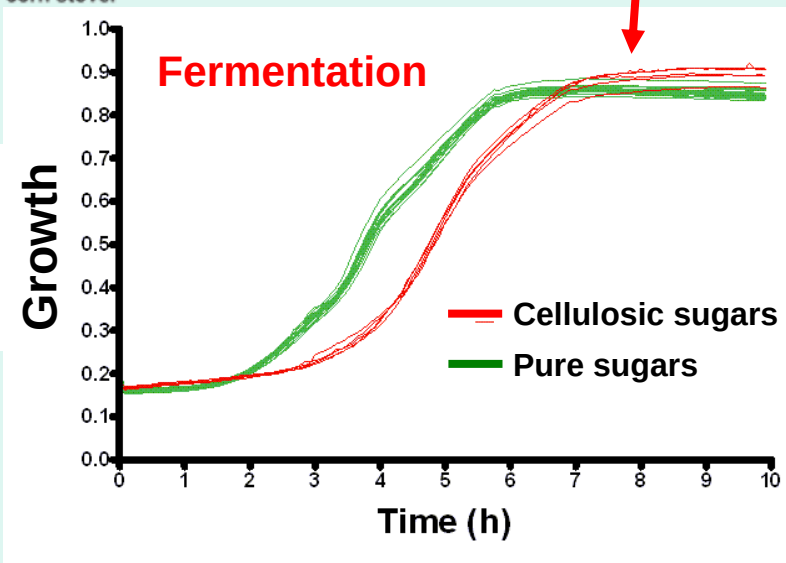
Growth of bioenergy microbes on processed corn stalks

untreated corn stover





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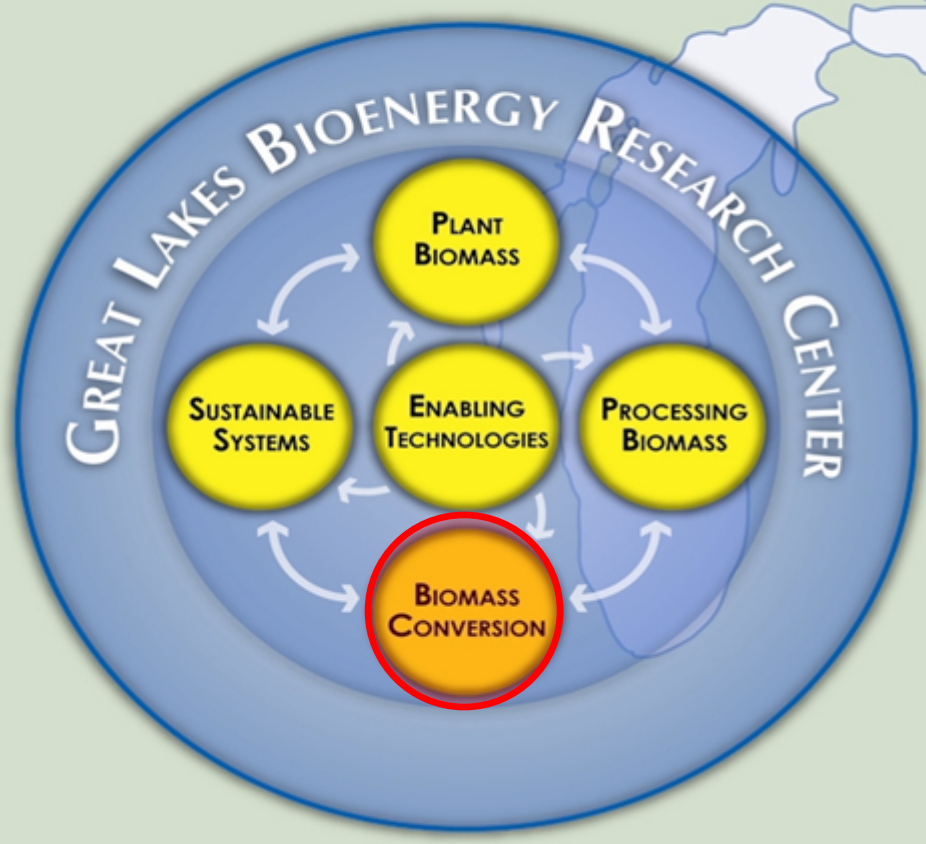

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Improved Bioenergy Sustainability

High Input, Low Diversity (annuals)

Develop **economically viable & environmentally responsive ecological, agricultural & life cycle practices (WI & MI Agricultural Stations)**

Low Input, High Diversity (perennials)

Continuous Corn
Corn-Soybean-Canola

Monoculture Switchgrass/ Legumes

Poplars

Native prairie
Early successional

Overcome bottlenecks in agricultural, industrial, & behavioral systems to

- **Improve carbon neutrality** & **greenhouse gas mitigation** across the entire biofuel life cycle at multiple scales
- Improve **ecosystem services** in biofuel landscapes (e.g. **water, soil & air quality, biodiversity, pest suppression, land use**)

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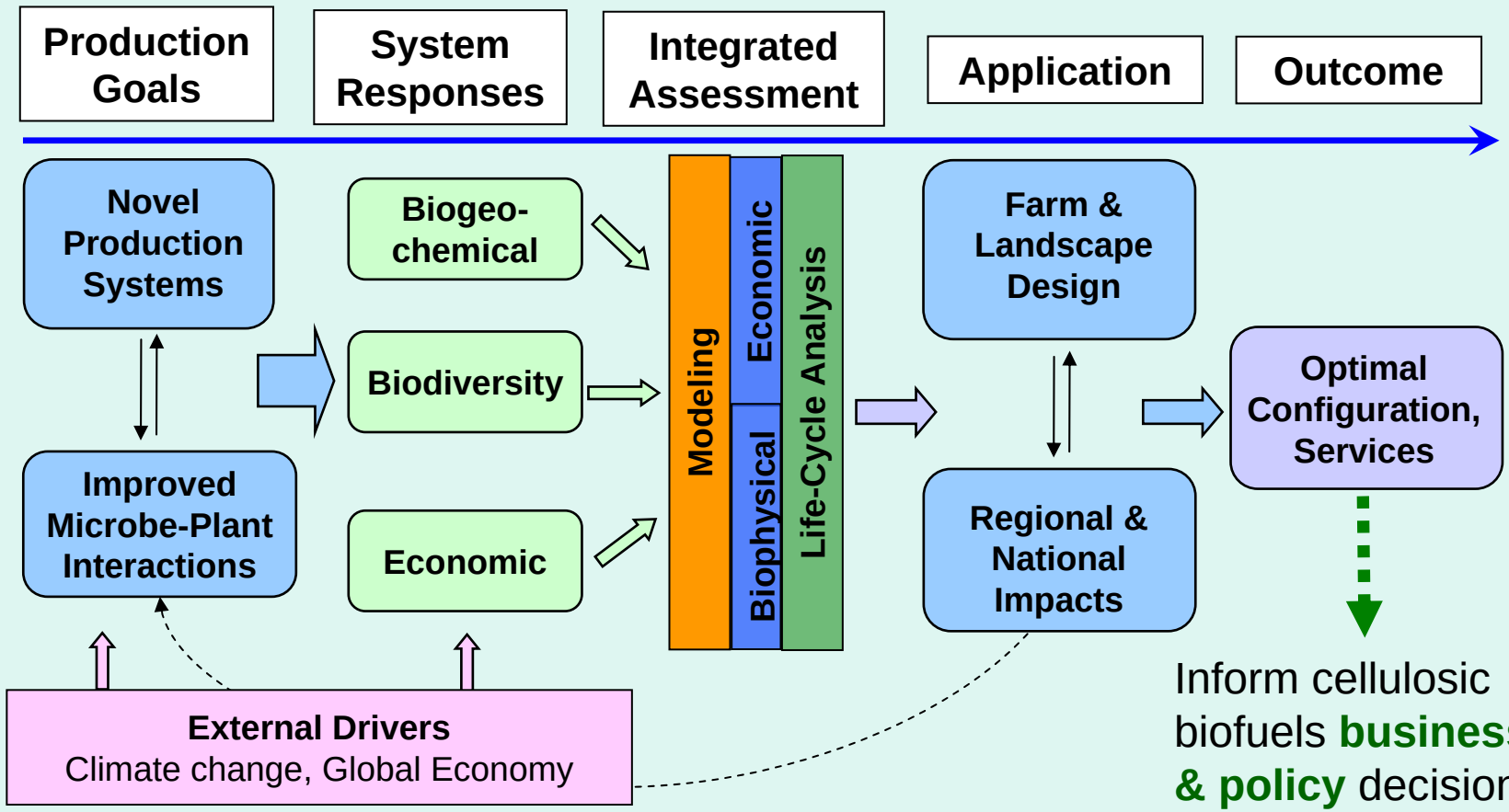
Sustainability Research Goals

➢ Predict elements of **integrated** biofuel production systems that can be **optimized to improve environmental & economic sustainability**



Inform cellulosic biofuels **business & policy** decisions

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Cellulosic Biofuels:

An obvious new venue for the Wisconsin Idea

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